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Sailing Past a **Billion**

Racing yacht design researchers push flow simulation past a meshing milestone.

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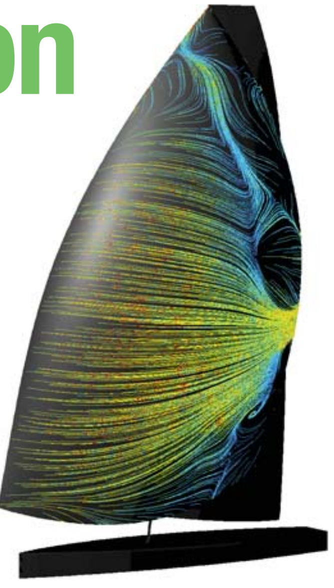
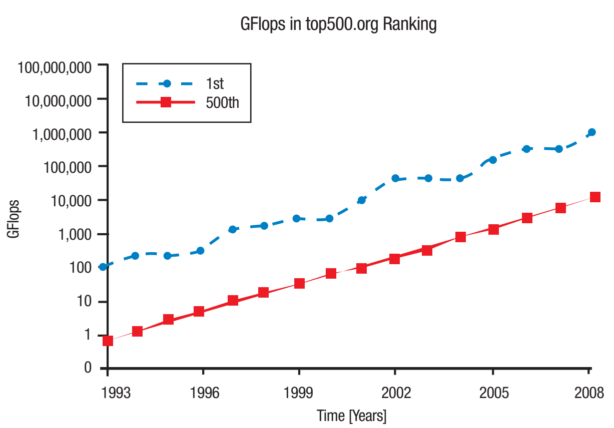
Over the last few decades, the development of techniques in computational fluid dynamics (CFD) together with the increasing performance of hardware and software have helped engineers understand the role of geometrical and mechanical factors on external aerodynamics in ways that were nearly intractable in the past. In recent years, several leading America's Cup sailing teams have become top-shelf users of flow simulation software by pushing the envelope of existing meshing and solver technology. Just a decade ago, experiments on physical models — using wind tunnels and towing tanks — were the main tools for the top teams in their external aerodynamic and hydrodynamic investigations. The option of simulating a number of boat designs in a virtual environment has been shown to have several advantages, including full control of all the parameters involved, repeatability of the measurements, and the ability to simulate nonstandard sailing condition scenarios.

In the 2003 America's Cup, in New Zealand, only a few racing syndicates had adopted fluid flow simulation as an effective design tool, though by the 2007 Cup, in Spain, almost all of the 12 competing teams had recognized the value of investing resources in both experimental tests and computational research. Nevertheless, for several technological reasons, there is still a reliability gap between experimental- and simulation-based results. One of these is the extremely complex flow around a racing yacht, particularly in downwind conditions.

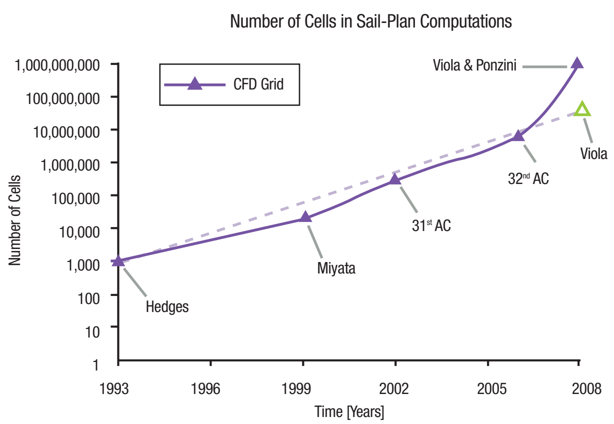
To design the sail plan for an International America's Cup Class yacht, a model-scale boat is commonly tested in a wind tunnel. To perform the same test in a virtual environment, all of the turbulent scales of the wind need to be simulated — from the largest, which draw energy from the mean flow, to the smallest, which are associated with the viscous dissipation that extracts energy as heat. It is possible to estimate the overall number of cells required to simulate all of the turbulent scales. This theoretical cell count is directly related to the Reynolds number, which is the ratio of inertial forces to viscous forces, and it is of the order of 10 billion. If such a number



Oil-flow pathlines just above the yacht model surface. The observed tracks, colored by velocity, are painted by the wind and simulate a classic wind tunnel experiment. Converging lines show separating or re-attachment regions.



Increasing computational capabilities of the last 15 years, expressed in Gflops (billions of floating point operations per second) and published by the official worldwide ranking top500.org



The increasing trend of the number of cells adopted in downwind CFD simulations. Very similar behavior is shown compared to increasing computational capabilities, with the exception of the groundbreaking billion-cell computation.